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Solar drying of strawberry coated with nopal mucilage: It's effect on phenolic compounds

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Abstract

The objective of this study was to evaluate the effect of indirect solar drying (ISD) and conventional (CD) (40, 50, 60 °C) on the concentration of phenolic compounds of strawberry slices, coated with opuntia mucilage (Opuntia ficus indica), and measured with the spectrophotometric method. The indirect solar dryer uses solar-thermal and photovoltaic technology with temperatures between 40 and 60 °C. The concentration of anthocyanins was higher in the ISD than in CD. The strawberry coated with the nopal mucilage has a preservation of phenolic compounds in CD and IDS.

Keywords: *strawberry, solar drying, phenolic compounds.*

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1. Introduction

The nutraceutical compounds are active biological substances that can be found in foods as natural compounds, they may provide nutritional and health benefits (Amarante et al, 2001), as well as, the prevention of diseases and improvement of the physiological functions of the organism (Garzon, 2008). Strawberry contains nutraceutical compounds as flavonoids, phenolic compounds, and anthocyanins (Giampieri, Tulipani, Alvarez-Suarez, & Quiles, 2012). The study of conditions and pre-treatments for hot-air drying are necessary to minimize the physical and chemical changes during the process. New quality products, attractive to the consumer due to the nutritional value, can be obtained (Adiletta et al 2016).

A pre-treatment as mucilage coatings lead to increased raw strawberry shelf life and improve effects on color, texture, and sensory quality of the fruit (Del Valle et al, 2003). Opuntia genus is widely known for its mucilage production (Saenz et al, 2004). Mucilage, a natural polymer with a great capacity to absorb water, is considered as a potential source of industrial hydrocolloid (León et al, 2010). Mucilage contains L-arabinose, D-galactose, L-rhamnose and D-xylose and galacturonic acid (Sepúlveda et al, 2007).

Drying is the most expensive unit operation due to the energy requirements in the drying chamber, as, heating by gas, electricity, or biomass. However, the price of fuel is the main economic factor that affects drying operations; also; the pollution and the environmental consequences of this process (Babu et al, 2018).

Solar energy is harnessed to improve solar heating systems in drying, using equipment for controlling the air flow and the greenhouse effect (Kamruzzaman et al 2017). Solar dying equipment improves the protection of the product against environmental contaminants (Abhay et al 20017). It also improves the protection of the product against environmental contaminants (Sharma et al, 2009).

The solar dryers can be the direct, indirect and mixed type, with or without forced convection (Ramana, 2009). In the indirect solar dryers, the solar collector for air heating and the drying chamber are separated (Mahesh et al 2016). The air is heated in the collector and solar radiation does not affect the food placed into the drying chamber. The drying is faster compared to open sun drying due to their shape and dimensions (Lingayat et al, 2017). Solar dryers design generally needs air ventilation system guarantees adequate moisture removing from inside them, environmentally friendly concept, seeking energy efficiency and using easily accessible materials (Visavale, 2012).

2. Materials and Methods

The strawberry was obtained from the local market in Morelos, México. The fresh strawberries were washed and disinfected with a colloidal silver solution in the concentration indicated by the supplier. They were subsequently rinsed to remove any remaining residue. The samples were selected manually, and the sepal and wick eliminating.

2.1 Color

The color of raw strawberry was measured during drying according to L * a * b * values. The parameters a * and b * were used to calculate the Hue angle according to the following equation:

$$Hue = \mathrm{Tan}^{-1}\left(\frac{b^*}{a^*}\right) \qquad [1]$$

2.2 Moisture

The determination of moisture content of raw strawberry coated with opuntia mucilage (*Opuntia ficus indica*) was measured during drying using the AOAC 972, 1990 method.

2.3 Coating (Opuntia ficus indica)

The opuntia mucilage extraction was carried out from cladodes of 6 months, harvested in the month of January. A cladode: water (1:2) ratio was used. Cladodes were cut into slices of 1 x 1 cm. The slices were weighed and placed in a stainless-steel container with distilled water. The heat treatment was carried out for 3 minutes at 80 ° C with constant stirring. The mucilage was separated by decantation method and refrigerated (Lopez-Ortiz et al, 2016).

The coating method used for the present project was by immersing and emerging the strawberry in the nopal mucilage for its subsequent placement in the dryer trays.

2.3 Conventional drying

Three temperatures (40, 50 and 60 ° C) were tested with an air velocity of 1 m/s.

2.4 Indirect solar drying (ISD)

The experimental indirect solar dryer system (ISD) was previously described in (Castillo-Téllez, Pilatowsky-Figueroa, López-Vidaña, Sarracino-Martínez, & Hernández-Galvez, 2017). The indirect solar dryer consists of a horizontal tunnel of rectangular shape with a constant section of flow with forced convection. Five flat plates solar collector for water heating was used. A radiator type heat exchanger was used for air-water heat transfer. Food samples were placed into the indirect solar dryer. For the air flow was an impulse by a fan connected to five photovoltaic solar panels. Temperature and air velocity were registered using a data acquisition system. The air velocity into the dryer was according to the solar irradiance (Gama, 2007).

Fresh strawberry coated with opuntia mucilage were placed in plastic meshes and introduced in the drying chamber. Fresh strawberry coated with cactus mucilage were placed in plastic meshes and introduced in the drying chamber. The air velocity in this dryer was according to the solar irradiance.

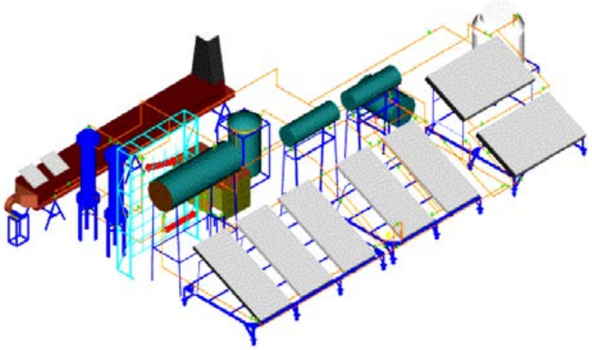

Fig. 1 Indirect solar dryer type tunnel

2.5 Data acquisition

The solar irradiance was obtained from the meteorological and calorimetric station of the UNAM. The geographical location of the Instituto de Energías Renovables - UNAM, in Temixco, Morelos, (18.85° latitude North and -99.2333° longitude East and an altitude of 1219 m above sea level). The solar dryer was instrumented with thermocouple T type temperature sensors, in different points: entrance and exit of solar collectors for water heating, entrance, and exit of the heat exchanger and along to the interior of the tunnel type-drying chamber. Temperature reading time intervals every 30 s. The water flow for heat exchanger was controlled at 10 L/s. The air velocity was measured and recorded with an anemometer at the entrance of the drying chamber.

2.6 Determination of anthocyanin

The pH-differential method was used to determine the total anthocyanin content (AC) according to the methodology reported by Giusti and Wroldstad (1996), using two buffer systems: potassium chloride buffer (0.025 M, pH = 1.0) and sodium acetate buffer (0.04 M, pH = 4). The content of anthocyanins was calculated as equivalents of Pelargonidin-3-glucoside (molecular weight (MW) = 449.2 g/mol, molar extinction coefficient (ε) = 26,900 L/mol/cm), the dilution factor (FD) of 0, was taken as the value of $A_{vismax515}$ and A_{700nm} for the sample of the two pH. Quartz cells of 1 cm light passage.

$$A= (A_{vismax} – A_{700nm})pH1 – (A_{vismax} – A_{700nm})pH4.5 \qquad [1]$$

$$AC\ (mg/L) = (A \times MW \times FD \times 1000) / (\varepsilon \times 1) \qquad [2]$$

3 Results and discussion

3.1 Color

The strawberry dried at 60 °C showed a change in color (darkening). The changes in strawberry coloring are due to different enzymes or chemicals, the degradation of the precursor’s compound of the red pigmentation in the strawberry is labile to the prolonged exposure of temperatures. During drying chemical reactions are slowed down as water activity decreases.

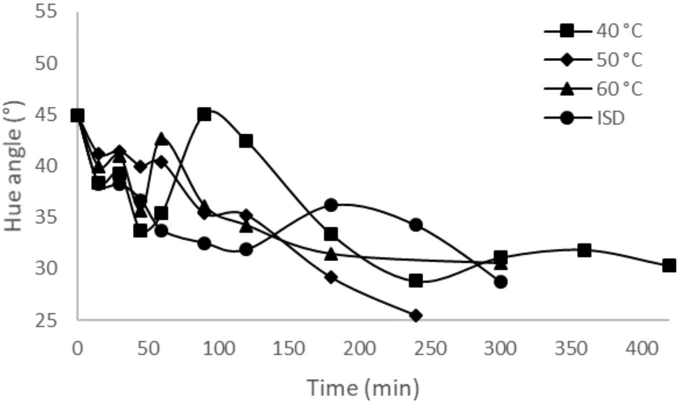

Fig. 2 Kinetics of color

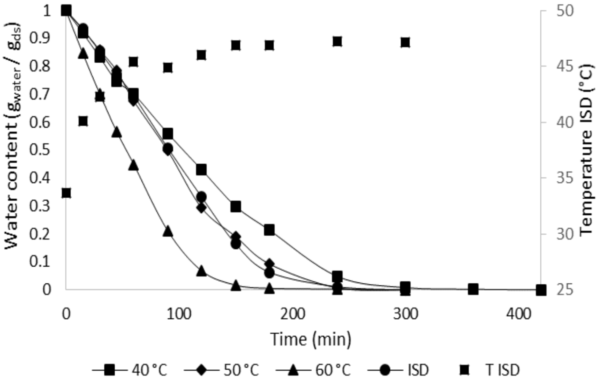

Fig. 3 Kinetic of moisture

3.2 Kinetic of drying

Drying time for 50, 60 °C and ISD were 5 hours, while at 40° C drying time was 7 hours. The coating does not affect the moisture transfer during the drying process (Lopez-Ortiz et al, 2016). During the first 180 minutes, it had major mass transfer during drying which includes the water transfer from inside of the strawberry to the surface and the water removal from the surface to the environment. Figure 3 shows two drying periods; in the first period, the conditions of the surface of the food reaches an equilibrium with the hot air conditions. The drying kinetics at 60 ° C shows a greater decrease in moisture content in the food reaching values of 9.8% wet bases after 300 minutes. Also, in the drying kinetics of the ISD can be observed that the moisture losses were low during the first 120 min due to the initial drying temperature (30 °C). After 120 min, the drying kinetic was similar to 50°C in the convective dryer. This behavior was due to the increment in the temperature during the solar day. The second period is when the food already loses most of the water there is a decrease in the rate of drying, which makes it difficult to moisture movement as noted from the 180 minutes until reaching 300 minutes, which represents the end of the dehydrated.

3.3 Measurements of solar drying

During the ISD process, the water inlet temperature, the inlet temperature of the tunnel-type solar dryer and the outlet temperature were measured, having a maximum of 62.47 ° C water inlet and after the water leakage 58.46 ° C, having a loss in water temperature due the heat transfer to the air, the maximum temperature difference was 15 °C ± 0.05 obtained at 13:30 hrs.

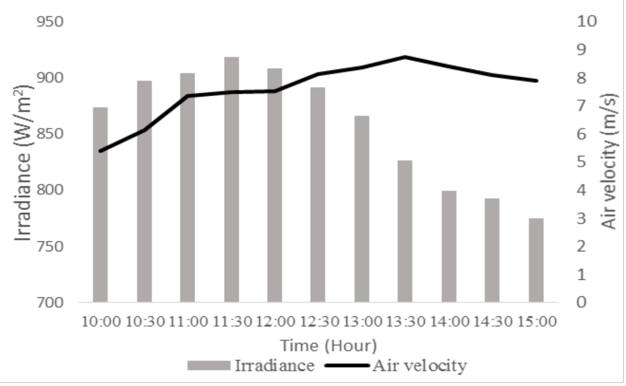

Fig. 4 Irradiance and air velocity during the solar drying process

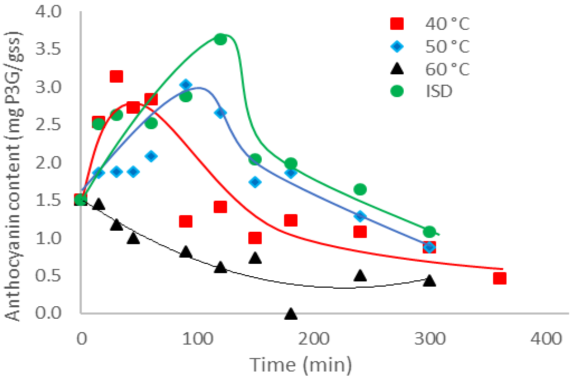

Fig. 5 Kinects of anthocyanin content

The initial direct irradiance measured during drying in the solar tunnel-type was 873 W/m^2 at 10:00 am and a final irradiation at the end of the drying of 774.2 W/m^2 at 15:00 pm. The maximum solar irradiance was 918 W/m^2 at 11:30 am, and the average was 858.96 W/m^2.

3.4 Phenolic compound: Anthocyanin

The anthocyanins were measured by the differential pH method in a double-beam spectrophotometer, of which 1 g of sample was used from its beginning until 60 minutes, after which the amount of sample for analysis had to be reduced to 0.1 g.

The samples were analyzed according to the dehydrated temperature having an initial concentration of 1.5 ± .3 gP3G/g$_{ds}$. For drying at 40 °C, 50 °C and ISD, the concentration of anthocyanin had an increment in until the 120 minutes, after this it had a diminution in its content. The diminution was due the compounds are sensitive to prolonged exposure to temperature, being affected after 150 minutes in the different two temperatures in conventional drier and indirect tunnel-type solar drier. The concentration of anthocyanin was mostly preserved in the tunnel-type solar dryer, considering a final content of 1.07 gP3G/g$_{ds}$, reducing 28.61 % of the initial concentration, unlike the different convection dryer dehydration temperatures (40 -68.92%, 50-42.2%, and 60 ° C-71.32%).

4. Conclusions

The coating does not affect the moisture transfer during the drying process. The drying kinetics at 50 °C was similar to drying kinetics in the ISD, besides of the nonconstant conditions in air velocity and temperature. The color in the dehydration at 40 °C in a conventional dryer had a minor darkening of the red color. The drying at 60 °C had a mayor darkening. The concentration of anthocyanin was greater preserved in the tunnel-type solar dryer, considering a final content of 1.07 g gP3G/g of Pelargonidin 3-Glucoside, preserving the compound in 34.70% in relation to the initial concentration.

5. Acknowledgment

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